PAPERS on Economics & Evolution

0812

In what sense do firms evolve?

by

Bart Nooteboom

The *Papers on Economics and Evolution* are edited by the Evolutionary Economics Group, MPI Jena. For editorial correspondence, please contact: evopapers@econ.mpg.de

ISSN 1430-4716

Max Planck Institute of Economics
Evolutionary Economics Group
Kahlaische Str. 10
07745 Jena, Germany
Fax: ++49-3641-686868

In what sense do firms evolve?

Bart Nooteboom
Tilburg University, the Netherlands
b.nooteboom@uvt.nl, www.bartnooteboom.nl

November 2008

Does evolutionary theory help, for a theory of the firm, or, more widely, a theory of organization? In this paper I argue that it does, to some but also limited extent. Evolutionary theories of economies, and of culture, have acquired considerable following, but have also been subject to considerable criticism. Most criticism has been aimed at inappropriate biological analogies, but recently it has been claimed that a 'universal Darwinism', purged of all such mistaken analogy, is both useful and viable. Why should we try to preserve evolutionary theory, and will such theory stand up to sustained critical analysis? How useful is it for theory of the firm? Evolutionary theory appears to be the most adequate theory around for solving the problem of agency and structure, avoiding both an overly rational, managerial 'strategic choice' view of organizations and a 'contingency' view of organizations as fully determined by their environment. Whether universal Darwinism stands up to critical analysis remains to be seen. Here, the focus is on evolutionary theory of organization and of knowledge. Use is made of a constructivist 'embodied cognition' view of cognition and of elements of a cognitive theory of the firm.

1 ISSUES IN EVOLUTIONARY THEORY

In this paragraph I discuss key issues in evolutionary theory for behavioural science, in order to specify the questions to be answered. The first issue concerns the need to abstract evolution from evolution in biology, in a more general 'universal' Darwinism. The second issue concerns the notions of replicators and interactors, and their meaning and relevance for organizations and knowledge. The third issue concerns the influence that interactors may have on selection conditions. The fourth issue concerns replication by means of imitation and communication, and its relation with the generation of variety. The fourth issue concerns the extent to which, and in what sense, variety generation is 'blind' and how it may be guided by experience in selection.

Universal Darwinism

Beyond biology, a generalized evolutionary framework, with its basic principles of *variety generation, selection and transmission*, has been applied to a wide range of socio-economic phenomena, such as organizations (Aldrich 1999, Baum and Singh 1994, McKelvey 1982), industries (Hannan and Freeman 1977, 1984, 1989), economies (Hodgson 1993, 2002b, Hodgson and Knudsen 2005, Metcalfe 1998, Nelson and Winter 1982, Veblen 1919, Witt 1993, 2004), knowledge (Campbell 1974), neural structures (Edelman 1987) and culture (Boyd and Richerson 1985, Hull 1988).

In behavioural science, the evolutionary perspective has a number of attractions. It accounts for development of forms (here forms of organization and of cognition) under

limited foresight. Wittgenstein (1976) spoke of language as a 'form of life', and perhaps evolutionary theory applies to all forms of life, in biology and culture. In economics and management evolutionary theory keeps us from the error of an unrealistically rational, magical view of development as the design by somehow prescient, or even clairvoyant, managers, entrepreneurs and scientists, as well as from the opposite error of institutional or technological determinism, whereby forms of organization are dictated by external conditions of technology and market (McKelvey 1982). In the first, managerial actors are omnipotent, and in the latter actors are absent. Evolutionary theory helps to deal with what in sociology is called the problem of agency and structure. It forces us to recognize both the role of actors, with their individual preferences and endowments, in the processes of variety generation and transmission, and the enabling and constraining conditions for action, in structures of markets and institutions, in the process of selection. While characteristics of entrepreneurs and organizations have a causal effect on survival and growth of firms, causality can also go to other way, with characteristics being the result of processes of selection and retention (Aldrich 1999, p. 336). It forces us to recognize causes of change both within organizations ('autogenic') and outside them ('allogenic') (McKelvey 1982). It makes allowance for the radical uncertainty of innovation (Shackle 1961), and for evident and ubiquitous error and failure in human endeavor.

Of great intellectual but also moral importance, evolutionary theory also forces us to accept diversity as an essential element of development and of societies. The old practice, in economic analysis, of dealing with an industry on the basis of a 'representative firm' is a fundamental mistake. As Hayek recognized, knowledge is dispersed and differentiated.

Competition in markets and fields of knowledge, with constraining and enabling effects of institutions, are straightforwardly seen as yielding a process of differential survival and retention of products, practices and ideas. There is plausibility in seeing entrepreneurship and invention as sources of variety generation, and to see personnel turnover, training, personnel transfer, imitation, consultancy and growth as mechanisms for the transmission of proven success.

Anyone who has studied socio-economic evolution recognizes that in many respects it differs radically from biological evolution. While earlier literature was often based on analogies from biological evolution, in more recent literature (Hodgson 2002b, Hodgson and Knudsen 2004, 2006) a radical abstraction has been made, in the definition of 'universal Darwinism' (Dawkins 1983) in terms of only the overall, 'meta-theoretical framework' (Hodgson and Knudsen 2006: 16) of *variety generation, selection and transmission*, regardless of the very different ways in which they operate in different areas of application. Hodgson and Knudsen claim that this overall framework applies universally to biological as well as economic, cultural, and cognitive systems. It is needed to explain why some organizations last longer or grow more than others, and why some are imitated more than others (Hodgson and Knudsen 2005, p. 6). While universal Darwinism gives a useful conceptual orientation of research, it leaves most of the explanatory work still to be done, in a specification of the processes of variety generation, selection and transmission, in terms of people, cognition, work, management, invention, innovation, organizations, industries, markets and institutions.

However, universal Darwinism goes further and specifies the principles of variety generation, selection and transmission in terms of the notions of *replicators* and

interactors (Campbell 1974, McKelvey 1982, Hull 1988) or *vehicles* (Dawkins 1983), and the notion of *populations.* Interactors/vehicles (in biology: organisms) interact with their selection environment, and are members of *populations* of similar but differentiated interactors (in biology: species). The suggestion is that these are essential elements of evolution, without which the notion of evolution becomes loose and indeterminate. They distinguish, it seems, Darwinism from a more general, looser, less determinate notion of evolution in the sense of 'development'. However, as argued recently by Nelson (2006), this is also where the problems begin. The question then is how meaningful evolutionary theory is if the notions of interactors and replicators fail to apply.

To function as an interactor, an entity must have a reasonably cohesive and stable set of components. This is the *ecological* side of evolution (Baum and Singh 1994). Interactors carry replicators (in biology: genes) that in the *ontogenetic* development of interactors generate characteristics of interactors that affect their survival and the replication of their replicators. This generation of characteristics (in biology: gene expression) takes place in interaction, within the interactor, between replicators and other features of the interactor, as well as with the environment of the interactor. Replicators may lie dormant until triggered by conditions. Note that it is not the replicators themselves that determine survival but the characteristics that they produce. Replicators may generate characteristics on different levels, including abilities to generate characteristics, depending on the circumstances.[i]

Replicators from surviving interactors are replicated and re-combined, mostly within populations of interactors that partake of a common pool of replicators. This is the *genealogical* side of evolution, in the *phylogenetics* of a species.

In economics, firms, in particular, are seen as interactors in their environments of markets and institutions in which they may go bankrupt, as members of industries that are seen as populations, and their competencies (McKelvey 1982) are seen as the corresponding replicators, with industries sharing a common pool of such competencies. In science, interactors presumably are most of all scientists, with survival here denoting career success, but what their replicators are is not so clear.

The contribution of this paper lies in the analysis of the three least researched aspects of evolution in social science (Baum and Singh 1994): the identity of interactors, the nature and characteristics of replication, and the process of variety generation. The structure of the chapter is as follows. First I give a discussion of key issues in evolution in social science, in order to specify the questions addressed in this paper. Second I summarize a theory of cognition used here, and the cognitive view of organizations to which it leads, as discussed in Nooteboom (2006, 2009). This yields a view on the possible nature of their replicators, their identity as interactors, and on intra- and inter-population differences between them. Third, I give an analysis of the sources of variation. The chapter ends with a summary of conclusions.

In the literature on organizations, the present discussion falls squarely in what Aldrich (1999) called the 'knowledge development' stream of organization theory. Here, use of insights from cognitive science is inspired by the fact that in socio-economics both replication and variety generation are fundamentally cognitive and linguistic processes (Nooteboom 2001).

Interactors and Replicators

The literature on evolutionary theory of organizations allows for connected evolutionary processes on multiple levels: of skills and jobs; of workgroups or *communities of practice* (Brown and Duguid 1996) within organizations (Burgelman 1983); of organizations within industries; and of industries in wider socio-economic systems (Baum and Singh 1994). However, it is not always clear what, precisely, the interactors and replicators are, on different levels. Here I focus on organizations as interactors in industries, and on scholars as interactors in disciplines or scholarly 'fora' (de Groot 1969). The following questions arise.

The most fundamental question, perhaps, is to what extent in socio-economics the notions of interactors and replicators make sense at all (cf. Nelson 2006). Unlike biology, in the evolution of organizations and knowledge replicators in the form of organizational competencies and scientific ideas do not depend on the survival under selection of the interactors that carry them, as noted e.g. by Nelson (2006). It is not even completely clear what 'failure' or 'being selected out' entails, and I will return to this point later. Whatever it means, competencies and ideas from organizations and scholars may be adopted by other organizations and scholars long after the latter have 'failed'. Often geniuses are not recognized, and their ideas are not adopted, until long after their death. Ideas can subside into obscurity, lurking in libraries, to be rediscovered or re-evaluated much later, without the need for intervening survival of its carrier. When organizations or scholars fail, whatever that means, some of their capabilities or ideas may still be seen as useful and adopted accordingly. Thus, purported replicators may float around, so to speak, disembodied from their carriers, possibly buried in unpublished documents, before they are replicated. If replicators may be disembodied from interactors, does the notion still make sense?

In biology, replicators generate, in ontogenesis, the interactors that carry them. In organization and scholarship, actors are not only active in interacting with their environment but also in cognitive construction, which entails that they develop their replicators, on the basis of experience (Witt 2005). As is widely recognized, ontogenetically produced replicators may be adopted by others, so that here evolution is, at least in part, Lamarckian, with 'inheritance of acquired characteristics'. Thus, while interactors may be generated by replicators they also generate them. Furthermore, according to the perspective of 'embodied cognition', to be summarized later, interactors develop in interaction with a variety of other people, adopting and transforming some of their ideas and skills. Thus they are generated by the replicators not only of any well-defined parent, but from a host of other interactors with greater or lesser 'parenthood'. The notions of 'parents' and 'offspring' become diffuse. While in biology there is a clear separation between ontogenetic and phylogenetic development, in society there is not (Witt 2005).

It is widely recognized that in social science interactors to some extent shape their replicators. For any remaining validity or usefulness of universal Darwinism, a key question is how far such shaping goes, and to what extent it reliably reflects selection conditions. Hodgson and Knudsen (2005) recognize that if direct shaping of replicators by their carriers were complete and fast, and would reliably reflect any shift or variety of the selection environment, evolution would break down. Survival would no longer be an indicator of success, and many unproven, worthless or deleterious traits would be imitated along with favorable ones. In other words, as recognized by most authors, for

evolution to work there must be some isolation of replicators from influence by interactors, or, in other words, some inertia of interactors (Hannan and Freeman 1984). My worry here is that the shaping of replicators may indeed to a considerable extent reflect often more or less erroneously perceived or inferred changes in the selection environment, in ways unproven by selection, and that indeed 'many unproven, worthless or deleterious traits (are) imitated along with favorable ones'. Here, Darwinism perhaps does indeed break down. In financial markets excessive risk taking took a long time before producing the present financial crisis.

For groups of people, such as organizations, to operate as interactors, in evolutionary terms there must be group selection. For that to work, individual interests must somehow be subjugated, to a sufficient extent, to collective interest. Organizational identity, cohesiveness and stability may be prevented by the dominance of centrifugal individual or group interests within the firm (Campbell 1994). So, what provides organizational cohesion and stability? Scholarly societies are also organizations, and a similar question arises there. In earlier and forthcoming work (Nooteboom 2000, 2006, 2009) I propose that organizations require an organizational 'cognitive focus' to limit 'cognitive distance between people inside organizations, in order to achieve exploitation of resources. Here I propose that such focus yields an organizational identity that has some stability.

Organizational focus enables but also constrains absorption of novelty that feeds organizational change. It serves as a filter for admitting and accepting outside ideas and people. In scholarly societies, established paradigms to some extent encapsulate the society from its environment. In other words, organizations are indeed subject to greater or lesser 'inertia' (Hannan and Freeman 1989). However, it still remains to be seen to what extent organizations may still escape from inertia. Indeed, the very notion of radical innovation seems to entail such an escape.

If organizations and scholars are interactors, what are their replicators? As indicated earlier, the meaning of the notion of 'replicators' has several dimensions: things that are carried by an interactor (1), generate the interactor's characteristics relevant for success in its interaction with its selection environment (2), and are transmitted to generate new interactors (3). McKelvey (1982) proposed that organizations are characterized by 'dominant competencies'. Nelson and Winter (1982) used the term 'routines', but there is some ambiguity and confusion around that term, and I prefer McKelvey's terminology. What, precisely, are these organization-level competencies? I would say that elements of organizational cognitive focus might qualify, plus technologies and skills. If scholars are interactors, are their replicators ideas, hypotheses, or theories? These entities can indeed be seen as being carried by organizations and scholars, to generate their organizational and cognitive identities, and to be subject to transmission to others. However, as already noted, those entities may also be transmitted as disembodied from their carriers, to adopters whose identities are formed from multiple sources.

To what extent can we meaningfully speak of 'replication' at all? Replication entails the maintenance, as a rule, of the content or properties of a replicator, with only occasional or limited 'copying errors', and without significant transformation of form, content or function. Is transmission of organizational competencies and of ideas sufficiently like that? In my view (cf. Nooteboom 2000) in communication significant transformation of meaning generally occurs, in the process of absorption or assimilation

into existing mental frames. Such assimilation is not a passive practice of copying but an active process of structuration and transformation.

For industries to make sense as populations of organizations, there must be both differences and similarities between firms within an industry, and possibilities for replication that are greater within than between industries. Due to imitation and personnel mobility between organizations in an industry, or even between industries, organizational identities may not be sufficiently differentiated and isolated for selection to work (Boyd and Richerson 1985). How do we account for intra- and inter-industry differentiation? In science, do disciplines make sense as populations? Or are the populations here scientific societies within or across disciplines, or are those to be seen as niches within disciplines?

In sum, the questions in this section are: what constitutes the replicators of organizations, in the form of organization-level competencies, how do these yield a cohesive and stable organizational identity, how does this yields differences as well as similarities within industries, more opportunities for replication within than between industries, and some but limited shaping of competencies as a function of experience in environments of markets and institutions. Partial answers have already been given. I will later analyze the questions in more detail.

Selection

In socio-economics, what is failure of interactors under selection? Is it the death of the interactor (organization, scholar), or some other manifestation of failure? In the context of firms selection arises from competition in markets, which may lead to their bankruptcy, take-over, break-up or management buy-out. As noted earlier, even in case of complete failure, in bankruptcy, some of its capabilities may be adopted as useful by others. In science, selection takes the form of refutation, ideally on the basis of empirical falsification (Popper 1959), or other critical debate in scientific 'fora', rejection of papers by journals and rejection of proposals for funding research. This may kill, but only one idea or publication, which may subsequently be revised or improved to survive later in a different form.

Also, as noted by Witt (2005) and Nelson (2006), particularly in economics and science there is much 'pre-practice' testing, in mental thought experiments, debate, computer simulations, the testing of physical prototypes, market testing and consumer focus groups. Human beings learn testing and experimentation before practice at an early age, in child's play, and proceed to refine their mental experimentation in later education. Such outside-practice testing would have to be included in the notion of selection. However, that means that some selection is not in the selection 'environment' but internal to an individual actor or organization.

A key issue in evolutionary theory of organizations and scholars is that singly or collectively they can to a greater or lesser extent affect or even mold the external selection environment of markets and institutions to favour their survival and reproduction, in 'co-evolution' or 'niche-construction' (Aldrich 1999). Selection is political, and is shaped or avoided by debate, rhetoric, indoctrination, coalition formation and positions of power and influence (or the lack of it). Are these to be seen as part of selection or as avoidance of it? While influence of interactors on the selection environment, in co-evolution, is not unique for socio-economics, and also occurs to a

considerable extent in biology, in economic systems the scope for it seems to be of a different order of magnitude, on the basis of some intelligent inference of selection forces and the ability, power and political influence of some organizations to shape such forces, in setting standards of technology, conditions of legitimacy, shaping market structure (e.g. distribution channels), and erecting entry barriers.

An example of the setting of selection conditions from Garud and Rappa (1996) concerns the rivalry between competing technologies for hearing aids in the form of implants in the cochlea, in the inner ear. There were two rival systems: a single channel and a multiple channel device. The first carried less risk than the second did, but the second yielded a greater and easier improvement of hearing. The problem was that objective, independent measures of these dimensions of performance were not available, and the balancing between them is subjective. The same ideas that informed the choice of device also informed the methodologies for selecting between them, so that there were rival evaluation methods. The rival methods were championed by rival commercial interest groups, and the stakes were high. The single channel group argued that the obvious choice was to begin with the low risk device, and step up to the other after its risks were clearer and could be reduced. The multiple channel group argued that this would not reduce risk but add to it in the process of taking out one device and replacing it with the other. No objective experience was available to back up either claim.

Let me give another illustration. In the innovation of a cotton carpet (instead of wool), it was first introduced for bedrooms, in view of the moisture regulating properties of cotton and its nice feel to bare feet. However, cotton fiber does not have the natural resilience of wool, so that in use the pile of a cotton carpet rapidly flattens, but after vacuuming regains its fresh look. Now, resistance of carpets to such pile flattening was a key feature in the existing certification of quality, thus favoring wool over cotton, and the new carpet could effectively enter the market only after the innovator, sufficiently large and influential, managed to wield his influence to have the certification procedure modified to accept vacuuming prior to inspection. Such actions to mold the selection environment are also amply illustrated by Aldrich (1999: 334).

In science, when scholars face a lack of survival and replication of their ideas, in failed access to journals, or in their papers remaining ignored or uncited, they can, and often do, create their own selection environment by founding their own scholarly societies with their more or less proprietary journals. Their ideas survive not only, and perhaps not even primarily, from their scientific as much as from their organizational and rhetorical skills.

One may argue that even though for these reasons selection may be limited or inefficient, not even the most visionary entrepreneur, nor the most powerful of corporations, nor the most able organizer or rhetorician can completely mold his environment to guarantee success, survival and dominance, and some selective pressure will remain. The limits are not only limits of power, but also cognitive limits. One is not infallible in inferring what structure of selection favours differential survival and growth, for lack of insight in causalities of selection and in opportunities that any change might yield to unforeseeable new innovations that may constitute a threat to incumbent organizations. Returning to the example of the cotton carpet, the most salient thing is perhaps that it took effort to alter the selection conditions, even in only one though crucial respect, which might have failed, in which case the innovation would likely not

have survived. While there is much more to be said about this issue, it is not a subject for the present paper, since although selection seems very imperfect it still seems sufficient to let this issue pass. In sum, for the sake of argument here I will accept that selection by competition still makes sufficient sense, in markets and scientific rivalry.

Replication

A third issue concerns processes of replication, and the relation between replication and variety generation. In socio-economic evolution, replication entails reproduction and imitation of knowledge and competencies, on different levels. This occurs on the basis of observation, communication and apprenticeship. Successful products and practices are copied or imitated on the basis of observation and inference, reverse engineering, publications and documents, oral presentations, courses, reports and explanations by consultants, and the like. Apprenticeship may merit special notice. Knowledge is externalized not only in speech, documents, software and ostensive activity, or role models, but is also embodied in tools, in a general sense including machines, procedures and forms of organization. In learning to use tools, an apprentice may reconstruct some of the mental schema's that lay behind the design and production of the tool.

In socio-economics, these forms of replication entail linguistic processes of expression, sense and reference, and cognitive processes of assimilation into mental *schemata* (Aldrich 1999, Piaget 1970, 1974) or *mental models* (Johnson-Laird 1983) that constitute *absorptive capacity* (Cohen and Levinthal 1990). Fundamentally different from replication of genes in biology, replication of knowledge and competencies is:

- At least partly voluntary and subject to choice: one adopts what is perceived to be successful
- Partial: one may, within restrictions of systemic coherence, adopt only part of a bundle of replicators carried by a given interactor
- Subject to decay, distortion, reduction, extension and transformation (going far beyond the copying errors, deletions and duplications of genes in biology). In other words, replication at the same time entails a kind and a degree of variety generation.

This issue will be analyzed with the use of insights from the perspective of 'embodied cognition'.

Variation

A fourth issue, in evolutionary theory, and this is the third subject for the present paper, concerns the sources of variation, in particular the question how blind and how independent from selection variety generation is.

According to most evolutionary accounts, the main trigger of radical innovation is a shock in the form of a break or shift of the selection environment, which may increase competition for scarce resources, disadvantage incumbent species, and create new opportunities for new variety. Such a shift or shock may be due to natural disaster, political upheaval and war, a shift in demand, a shift in institutions (e.g. regulations for protecting the environment), or a shift due to developments in related industries or markets. However, this tells us only of new opportunities, of how radical innovation is enabled or triggered, not of how it is generated.

In evolutionary theory, generation of new variety, in new interpretations or new ideas, is generally ascribed to errors in replication, and random, uninformed trials as steps into the dark ('mutations'). In the methodology of complex adaptive systems (Holland 1996), the conduct of agents is modeled in terms of if-then rules, which are sometimes modeled, in analogy to chromosomes, as bit-strings of messages sent in response to bit-strings of messages received, and the discovery of rules is modeled as random mutations of values at positions in the string plus random crossover of strings, in analogy to sexual reproduction. How valid or adequate is this, as a model of human learning and communication?

In socio-economic evolution there is no doubt much trial and error in entrepreneurial venturing, and more so to the extent that the innovation is radical, i.e. entails destruction of existing competencies (Anderson and Tushman 1990, Tushman and Anderson 1986), technologies, and forms of organization, limiting the opportunity to build on existing knowledge and competence. However, evidently in socio-economic evolution there is invention and knowledge development that is informed, somehow, by experience from failures and resulting inferences about where sources of failure may lie and where to look for improvements. This is too obvious to ignore or deny, and Aldrich (1999), Foster and Metcalfe (2001) and Nelson and Winter (1982), to name only a few, all recognized that next to blindness there is also intentional, deliberate, and somehow directed variety generation.

Thus, according to Foster and Metcalfe (2001: 10)

> 'The rate of economic progress that we observe reflects guided variation within conceptual schemes that channel explorative, creative enquiry in particular directions'. However, they immediately add: 'Of course, all variation is, in effect, blind variation, since it necessarily deals with the unknowable consequences of a present decision.'

What does it mean that variation is both guided and blind? Little, if anything, in the evolutionary literature, is said how the 'guidance' or 'direction' of variation works in 'explorative, creative enquiry'. More generally, the generation of variety is the least developed side of evolution in socio-economic systems (Baum and Singh 1994, p. 18).

According to Hodgson and Knudsen (2005, p. 11) evolution is blind in two senses. First,

> … particular outcomes are not necessarily prefigured or predicted in advance.

I agree with that. However, this leaves open the possibility of an intelligent design of a heuristic path of discovery, guided by experience from selection, that is likely to yield radical novelty, even though it cannot be predicted what that will be. That is precisely what I will argue.

According to Campbell (1987),

> .. any capacity for foresight or prescience must be based on tried and tested knowledge, otherwise we have no grounds to presume its effectiveness. Accordingly,

> when genuine innovations are launched, we are unable to assess the probability of their success or failure (Hodgson and Knudsen 2006, p. 11).

I agree with the first part (experience is needed to presume effectiveness) but I disagree with the second part. Because we can make inferences from experience we can 'presume effectiveness', i.e. increase likelihood of success beyond blind trials, even if perhaps that cannot be rendered in terms of probability theory (cf. Shackle 1962).

Campbell (1974) specified blindness as entailing variations that are (1) independent of each other, (2) separate from the environment, (3) uncorrelated with the solution, and (4) later variations are not corrections of former ones. Applying these criteria, I will argue that there is non-blind variation.

The often-heard claim that a theory of invention would be self-defeating or even self-contradictory, because by definition invention cannot be predicted, is based on confusion between prediction and explanation. One can claim to have some understanding of processes of invention without thereby claiming to be able to predict its outcomes. That applies to evolutionary theory more broadly: it explains principles of process without claiming to predict its outcomes.

In the evolutionary literature, some authors have allowed for variations that are guided from higher level, variety generating 'search' routines (Nelson and Winter 1982). Other literature also suggests that there are higher level 'dynamic capabilities' that direct the change of lower level capabilities (Teece et al. 1997). Dynamic capabilities include rational inference of cause-effect relations, rules for experimentation, and ability to utilize organizational memory. They also include exchange of codified knowledge with others, in what (Nonaka and Takeuchi 1995) called 'knowledge combination' and Zollo and Winter (2002) later called 'deliberate' as opposed to 'experiential' learning. So, the question now is to what extent, and how, organizations can develop dynamic capabilities to escape from inertia. In what sense, and to what extent is this blind? How is it related to selection, and to what extent can it anticipate success in selection?

2. ORGANIZATIONS, INDUSTRIES AND SCIENTIFIC COMMUNITIES

In this paragraph I analyze the identity of organizations as interactors in terms of the notion of organizational cognitive focus and its cultural expression, differences between organizations within and between industries, seen as populations, and the 'isolating mechanisms' between populations. I start with a summary of the 'embodied cognition' view used here, and its application to theory of the firm, taken from (Nooteboom 2000, 2009).

Cognitive theory

Briefly, the embodied cognition view claims that people perceive, interpret and evaluate the world according to mental categories (or frames or mental models) that they have developed in interaction with their social and physical environment. Since the construction of cognition takes place on the basis of interaction with the physical and social environment, which varies between people, 'different minds think different things', as was recognized by Austrian economists (Lachmann 1978), and there is 'cognitive

distance' between people to the extent that they have developed their cognition in different environments (Nooteboom 1992, 1999). This connects with Hayek's view of localized, distributed knowledge. As a result of context-dependent cognitive structuring, cognition is bounded not only in the sense that one has a limited capacity for rational evaluation, but in the more fundamental sense that one's perspective is biased by experience.

Cognitive distance between people, resulting from variety of experience, presents both a problem and an opportunity. The opportunity is that variety of cognition is a source of innovation. The problem is that to the extent that cognition differs, it is more difficult to understand each other and to collaborate and utilize opportunities from cognitive variety. Note that, cognition being a wide concept in this paper, cognitive distance entails both difference in intellectual knowledge and difference in feeling and morality. Cognitive distance yields not only a difficulty of mutual understanding, or limit to absorptive capacity (Cohen and Levinthal 1990), but a wider difficulty of collaboration, including a mismatch of moral and motivational aspects of collaboration. In other words: distance includes issues of both competence and governance.

Optimal collaboration requires a trade-off between the upside and the downside of cognitive distance, seeking 'optimal cognitive distance', large enough to offer variety for innovation, and small enough to enable collaboration. Here, I propose, lies the fundamental purpose of firms, and organizations more in general. That purpose, I propose, is achieved by means of an organizational cognitive focus, which has both intellectual and moral/emotional features. To function as a coordinated system of actions, organizations need some more or less specialized shared language or jargon, perceptions, understanding and morality, as part of organizational culture (Schein 1985). Without such focus of shared perceptions, meanings, understandings and values, too much effort, time and aggravation would have to be spent to disambiguate meanings, eliminate misunderstanding, set priorities, establish directions, coordinate activities, align incentives and negotiate the terms of collaboration. This is the view of organization as a system for 'sense-making' (Weick 1995), 'collective mind' (Weick and Roberts 1993), system of 'shared meanings' (Smircich 1983). Witt (2005) offered a related view of entrepreneurs as providing 'cognitive leadership'.

To achieve focus, organizations develop their own specialized semiotic systems, in language, symbols, metaphors, myths, and rituals. This is what we call organizational culture. This differs between organizations to the extent that they have different goals and have accumulated different experiences, in different industries, technologies and markets. The central difference between firm and market is that in the former such focus is made and in the latter it is not, or to a much lesser extent (there still is a remaining, shared cognitive focus from shared national or regional culture). Thus the market has the higher *potentiality* of variety of performance, and the firm has the higher *actuality* of performance.

On the competence side, focus is needed to *enable* people to understand each other and connect complementary knowledge, without unduly restricting variety and creativity. On the governance side, focus is needed to *motivate* people to collaborate and share and connect knowledge, without unduly restricting autonomy, ambition and competitive spirit.

Organizational focus also has a function of both selection and adaptation of people. In selection, it selects people, in recruitment but often on the basis of self-selection of

personnel joining the organization because they feel affinity with it, and adaptation, in socialization into the firm, and training, of incoming personnel. To perform these functions, focus must be embodied in some visible form. Such form is needed for several reasons. One is to function as a signaling device to outsiders. That is needed as a basis of the (self)selection process of incoming staff, and for recognition and identification by other stakeholders, such as customers and suppliers. Another, deeper reason is to stabilize the mental processes associated with organizational focus. As such, materialization of organizational focus has the same function as the body has for individual cognitive identity. Cognitive activities in an organization require some embodiment to crystallize, direct and stabilize cognition and communication within the organization. Here we find symbols, such as logo's, and style of advertisement and external communication. More for the internal function of coordination, we find the exemplary behaviour of organizational heroes, often a founder of the organization, corresponding myths, and rituals. More formalized forms of organization are procedures, for reporting, decision-making, recruitment, contracting, and the like. Finally, if it is indeed true that cognition is constructed on the basis of interaction in a given environment, the shared environment of the firm will generate a certain similarity in further cognitive development op people within the firm.

Organizational Identity

Hodgson and Knudsen (2004) usefully argued that the cohesiveness of the interactor, needed for evolution to work, requires at least a core of components that stand or fall together with each other and with the interactor as a whole. More precisely, the probability of survival of one component is connected with the survival of other components in that core. The question now is how organizations achieve the cohesion and stability required for interactors.

The answer proposed here lies in the notion of an organization as a cognitive focusing device. The main point here, for the present paper, is that organizational cognitive focus, produced and reproduced by organizational culture, and by people socialized into that culture, forms the core of organization-level competence, to achieve coordinated bundles of competencies or capabilities. Organizational focus constitutes a cohesive (but not necessarily consistent) whole of perceptions, meanings and values that define roles, relations and procedures of interaction, and thereby yield the requisite cohesion and stability of organizations as interactors. Now, is it this focus or the set of capabilities that are coordinated by it that constitutes the set of replicators of an organization? Clearly it is the focus, since that is unique and specific to the organization, while the capabilities that it coordinates are on the individual rather than the organizational level, and are more universal, ranging across organizations, in professions.

How does this compare with McKelvey's view of replicators as 'dominant competencies'? There is no conflict if we see the latter as organizational rather than individual, and the cultural and cognitive elements of focus may be seen as a further specification of those organizational dominant competencies. Here, 'dominant' means that they are shared by at least a 'dominant coalition', and that they condition, i.e. structure, enable and constrain, actions, and have normative content or import. In other words: they are institutions. Thus I prefer to see the replicators as institutions rather than competencies, though they do constitute organizational competence. Nelson and Winter

(1982) speak of 'routines'. But, again, in view of their regulatory, constitutive and normative nature I prefer to see them as institutions. However, they are a specific kind of (organizational) institutions, and I prefer to simply call them elements of organizational focus.

While the *raison d'être* of organization as a focusing device is that it enables cognitive and moral coordination, for the sake of efficient goal achievement, and is therefore selected for in market competition, it also helps to create the stable and differentiated organizational identities needed for evolutionary selection of organizations to work.

Organizational focus emerges from the imprint from the entrepreneur who started the organization, is subject to some drift due to turnover of staff, and to shifts due to crises, caused, in particular, by shifts in the environment, or by new, challenging interpretations of the environment, and by the weeding out by selection, in population effects. When resources are scarce and competition is tight, selection is likely, in the long run, to yield organizational cognitions and structures that reflect the exigencies of the environment of markets and institutions. Consider, for example, the view that stable environments tend to favour 'mechanistic' environments while turbulent environments tend to favour 'organic' ones (Burns and Stalker 1961), or more specialist vs. more generalist organizations (Hannan and Freeman 1977). However, focus is stable because it is reproduced in action by people who are selected, partially self-selected, in recruitment, according to their affinity to the focus, are socialized into the organization, and further construct their cognition from the input from interaction in the organizational institutional environment. Recall, here again, that according to the idea of intelligence as internalized action, the further development of cognition reflects the environment, in this case the organization, in which cognitive construction takes place.

Organizational focus cannot be integrally and instantly re-shaped as a function of experience in selection, and this limits Lamarckian adaptation, and yields some organizational inertia. The limits to such change lie in the systemic cohesion of elements of cognitive focus and in the fact that cognitive focus serves as an absorptive capacity that tends to mostly confirm itself in its functioning (imprinting). However, and this will be discussed later, in the discussion of a 'cycle of discovery', there is a process by which absorptive capacity does transform itself in its functioning, so that there is some Lamarckian mechanism, and an escape from inertia, but in a series of conditioned steps that require time. It is an empirical question to what extent the speed of that is sufficient to escape from selective pressures.

Organizational Boundaries

The cognitive perspective of organization gives a new slant on organizational boundaries and on inter-firm alliances. Aldrich's (1999) definition of organization as goal-directed, coordinated activity systems (which I adopt) also includes the maintenance of more or less clear, stable boundaries (which I reject). Of course, boundaries of legal identity remain fairly clear, as they should (Hodgson 2002a), but organizationally there may be durable relationships between organizations, supported by some cognitive focus of shared perceptions, language and norms, even though that focus is less cohesive, and probably also less inclusive, than within organizations. In that sense, counter to Hodgson (2002a, 2006), it is quite legitimate to speak of 'fuzzy boundaries', in terms of elements of

organizational focus that are shared between organizations, and of common institutions, even while clarity of legal boundaries and legal identity is preserved.

While clear and stable boundaries may apply to most traditional organizations, it is much less the case for modern web-based, 'virtual' enterprises and network forms of organization. Apparently, the assumption of clear and stable boundaries is deemed necessary to yield the organizational cohesion needed to make evolutionary selection work. But why would entrepreneurs or managers want that selection to work? If with fuzzy and/or variable boundaries, imitation, and buy-out of personnel from other firms they can escape selective forces, why shouldn't they? The following conundrum then arises. If organizations are selected, in evolution, for their ability not to have clear and stable boundaries, while those are necessary for selection to work, how can this be?

My view is that the notion of cognitive focus is sufficient for a stable and cohesive identity of organizations while it does not require clear and stable boundaries of activity, and allows for parts of focus being shared with other organizations, as long as organizational focus is still distinctive. It may be that organizations make their focus so lacking in cohesiveness, with a small width, little or no reach, and little or no tightness, that boundaries are hard to establish, apart from the legal ones, and the firm becomes like a market. But then the organization would have hardly any identity left, and one could hardly speak of an organization any longer.

Organizational focus creates organizational myopia, more so to the extent that it is cohesive and inclusive, and in addition to all the other motives for inter-firm alliances, familiar from the extensive alliance literature, this gives an additional, cognitive reason, to prevent myopia by means of complementary outside cognition from alliance partners (in 'external economy of cognitive scope', Nooteboom 1992, 1999). Here, the notion of cognitive distance applies to organizations, as differences in shared language, meanings, perceptions, understandings and values and norms of behaviour. In empirical work measures of the cognitive distance between firms, or proxies for them, have been constructed on the basis of indicators from organizational data and technological profiles derived from patent data (Wuyts et al. 2005, Nooteboom et al. 2007).

Note here the condition, familiar from the alliance literature, that when organizations outsource activities they must often still retain absorptive capacity with respect to those activities to properly collaborate and coordinate with outside sources (Granstrand, Patel and Pavitt 1997). As indicated before, organizations may not have clear boundaries of activities, in sharing activities with other organizations, and may have shifting boundaries, in outsourcing and integrating activities, and may share elements of organizational focus with other organizations.

Intra-Population Differentiation

Within industries, cognitive distance, i.e. difference in organizational focus, is limited, particularly concerning the competence side of technologies and competencies, in shared technologies, market demand, market structures, technical and professional standards, etc., yielding what may be seen as a common pool of competencies (McKelvey 1982). As a result, staff exchange between organizations is feasible and can create and confirm the identity of an industry (McKelvey 1982: 197), yielding 'industry recipes' (Spender 1989). This is also enhanced by pressures towards conformity to dominant designs and practices from needs of efficiency and of social, political or financial legitimation

('mimetic forces', Dimaggio and Powell 1983). However, while firms may share component skills and technologies, particularly within an industry, their overall composition of capabilities and activities, in a coherent system, may differ substantially. But above all, organizations have their distinctive identities of cognitive focus.

As noted before, to the extent that an organizational system is systemic or complex, as defined earlier, piecemeal, local variation of single elements is problematic since it soon affects the integrity of the system as a whole. Then, when there is one difference between firms there tend to be many, in distinctive systemic wholes (Levinthal 2000).[ii] In sum, when operational structure is complex, even with similar components integrated systems may differ greatly.

For an illustration of this, consider the comparison, in the automobile industry, between the older 'Fordist' production system, and the newer 'Toyota' system (Coriat 2002). The differences are systemic. The Toyota system has a tight connection of mutual conditioning between the *goal* of small series of differentiated products, the *organizational principles* required by the 'demand pull' principle, such as integrated team responsibility for quality and scheduling, lack of hierarchical planning, zero stocks, and just in time production, *human resource principles* of multi-skilled workers, job rotation, and career prospects, and the *physical configuration* of machinery according to the sequence of value adding activities. One cannot change any of these components without changing others, and ending up in an entirely different system.

Also, even within industries organizational focus is more varied, and organizational cognitive distance is correspondingly greater, on the governance side of the moral, intentional, institutional order, in different styles or cultures of management. Deep differences in fundamental perceptions, views and (largely tacit) assumptions concerning man, his knowledge (e.g. objective or constructed), his relation with his environment (passive or active), his morality (basically good or bad), and relations with other people (egotistic or altruistic) (Schein 1985), yield differences in risk perception and acceptance, pro-activeness ('locus of control'), formality or informality, rivalry or cooperation, intrinsic or extrinsic motivation, instruments and styles of governance and conflict resolution. From an evolutionary perspective, the persistence of such differences, in spite of selection pressures, suggests that on the moral, intentional side there are different ways to be successful, at least temporarily, within an industry.

In industrial dynamics, a central issue is how to combine exploitation and exploration (March 1991). While earlier some industries were relatively stable, allowing for a focus on exploitation, and others were in a state of flux, yielding a focus on exploration, now the combination of the two is needed in most if not all industries, although the priority of exploitation or exploration varies, depending on the volatility of technologies and markets involved. Combination of the two is particularly difficult when exploitation is highly systemic, as defined earlier. Then, by definition, units within the system hardly have any room for the experimentation and deviation needed for exploration, since they would jeopardize systemic integrity. In that situation, exploration needs to be relegated to a different time or place. The classic case is the division between departments for production and for R&D. This yields the classic problem of divergent mentalities and priorities between them, with resulting misunderstandings, conflicts and recriminations. It is difficult, though not hopeless, to find an organizational focus that accommodates both. One method is to engage in cross-functional teams, and another is frequent staff rotation,

with an organizational focus to support that, mostly on the governance side, in values and norms of conduct that favour acceptance of differences in competence, work conditions, styles of thought and action, time framing, and tolerance of ambiguity and uncertainty. Another would be to create more flexibility by decomposing the exploitation system into more autonomous parts, accepting loss of exploitative efficiency for the sake of exploration. Such choices may be made differently by different firms, even within an industry, with corresponding differences in organizational cognitive focus.

As noted before, cultural differentiation between organizations is maintained, in spite of turnover and exchange of staff, because in the entry into an organization there is (self)selection according to expected fit to organizational culture, adaptation by socialization into organizational culture, and organization-specific cognitive construction.

Finally, there are differences in the content of focus. Some firms may emphasize surface level elements of focus, in more ad hoc specific rules and procedures, leaving wider variety in underlying thinking and values, while others may emphasize more generic deep level elements, with a larger degree of ideological indoctrination, in a stronger culture. The first has the advantage of greater liberty and scope for idiosyncracy, the latter has the advantage of faster response in new configurations of activity, and more intrinsic motivation.

Inter-Population Differences

Between firms in different industries there are greater differences, not only on the governance side but also on the competence side of cognitive focus. There are, for example, deep differences in professional skill. As McKelvey (1982, p. 202) phrased it '.. Would you fly on an airplane that had recently been staffed with non-airline employees? Would you enter a coal mine operated by hotel employees? Would you eat in a restaurant staffed by truckers?' However, even between industries isolation is far from complete, and replication across industries does take place. McKelvey (1982, p. 206) suggested that to the extent that organizations are simpler, characteristics are more easily exchanged, also between industries.

For an illustration, consider the emergence of self-service. It emerged in retailing, largely outside large firms, initiated by independents but swiftly adopted by large chain store firms after it proved a success. Self-service retailing constitutes a distinct 'species' from service retailing, with a different structural logic, in that a fundamental reversal of roles occurred between shop attendant and customer. In service, the attendant moves about to collect items for a shopper's basket, while the customer remains stationary at a counter, and in self-service these roles are switched, with the customer picking out its own goods, and a stationary attendant at a check-out, in a correspondingly different lay-out of the shop. This eliminated a limit to shop size. In a large shop, with many products, in the service mode the attendant would have to move about too far, with an unacceptable increase of waiting time for the customer. The emergence of self-service, with its consequent opportunity for larger shop size, was favored by a shift of the selection environment towards knowledgeable customers who no longer needed advice from shop attendants, an increased demand for less frequent, 'one-stop' bulk shopping, due to greater scarcity of time, enabled by transport capacity from car ownership and by refrigerated home storage capacity. In its turn, self-service affected selection conditions, in co-evolution, in that it enabled economies of scale that pushed out small shops. With

its demand for pre-packaged goods, it also had wide repercussions for the selection conditions in packaging and food industries. In replication, however, isolation with respect to other industries was very limited. The principle of self-service was quickly and widely adopted in other industries, such as restaurants and even hotels.

It is doubtful whether organizational focus could survive a merger or acquisition, and this contributes to their frequent failure. In view of greater difference in focus between than within industries, mergers and acquisitions are more likely to succeed within industries than between industries (Nooteboom 1999), and this is confirmed empirically by Bleeke and Ernst (1991).

Absorptive Capacity and Isolation

The notion of a population requires 'isolating mechanisms' between them. Baum and Singh (1994, p. 12) listed a number of such isolating mechanisms: technological interdependencies (restricting the replication of single, isolated elements from bundles), institutional pressures of isomorphism (Dimaggio and Powell 1983), complexity of learning (difficulty of absorption), resistance to learning, imprinting, and 'network closure' (with in dense networks members looking inward and locking each other into established patterns). This section further develops the more cognitive aspects of complexity and lock-in.

As indicated earlier, interactively constructed mental categories constitute our *absorptive capacity*: we *assimilate* input through our senses into those categories (Piaget) and in so doing make sense of them, interpret them, and make inferences on the basis of them. Thus it is better to speak of the 'reproduction' or even 'transformation' rather than the 'sharing' or 'copying' of knowledge. At greater cognitive distance assimilation is more difficult, replication is less complete and faithful, and more knowledge and interpretation will be 'added'. In other words, at larger cognitive distance replication is more limited and entails more variety generation.

Knowledge, in the form of mental schema's or frames corresponding with competencies, is often largely tacit and stored in 'procedural memory', as 'know-how', and can only imperfectly be codified into declarative knowledge of facts, logic and causal relations, as 'know-that' and 'know-why' (Cohen and Bacdayan 1996). Knowledge 'sharing', with minimal change of knowledge in communication, requires a certain commonality of absorption, or limited cognitive distance, as between practitioners of the same jobs (Miner 1991). There, mutual understanding is quick and largely implicit, with few words needed, in jargon. Communication will be less faithful and fast but next best inside work groups of people doing different jobs (Gersick 1988) or *communities of practice* (Brown and Duguid 1996).

Recall that mental schema's and cognitive distance include not only cognition in the narrow sense of intellect, but also more emotion-laden moral categories of how to deal with relational risks from mutual dependence and rivalry. Different ways of dealing with such risks are legal or hierarchical coercion, balance of mutual dependence, reputation, and less self-interested motives of ethical conduct, empathy, identification and routinized conduct (Nooteboom 1999). However, note also that mutual understanding does not by itself entail lack of rivalry. Indeed, rivalry may increase with similarity, if similarity entails competition, and between professionals in the same field, or in the same

organization, rivalry may be greater than between professionals in different fields or organizations.

While cognitive distance yields some 'reproductive isolation', with limited replication, maintaining distinctive identities of organizations and industries, that isolation is far from perfect, for two reasons. First, on the level of communities of practice, outsiders from different communities can enter and become members, after some time needed for initiation and socialization, in *legitimate peripheral participation* (Lave and Wenger 1991). Second, even at large cognitive distance one may still be able to selectively assimilate single but crucial elements of externalized knowledge, even from distinct industries. The case of self-service, emerging in retailing but copied by restaurants, discussed earlier, gives an illustration.

Scientific Communities

Scientific communities also may be seen as populations to the extent that there are adequate isolating mechanisms between them. That would entail obstacles to inter-group and interdisciplinary research, and such obstacles indeed exist, though perhaps more for the behavioural than for the natural sciences. To a greater or lesser extent, sciences are prone to the following social dynamics. Novelty often is shielded off by an established 'mainstream', for reasons that will become apparent in the following. Innovators then often create a following of their own, develop their prominence in it, push it or are dragged along by vested interest in reputation and serve, or are high-jacked, as role-models, with their achievements as exemplars to be emulated by their following. Exemplars settle into paradigms that sometime harden into dogma. Typically, the founding fathers figure as editors or prominent members of editorial boards for journals that form the platform for the society's goals and ideas and constitute a niche with its dedicated selection environment.

An example in economics is the International Joseph A. Schumpeter Society (ISS), as a haven for Schumpetarian and evolutionary economists, with its proprietary 'Journal of Evolutionary Economics'. Another is the European Association for Evolutionary Political Economy (EAEPE), as a haven for unorthodox institutionalist economists, with its recently instituted 'Journal of Institutional Economics'. In management science, a recent example is the European Academy of Management (EURAM) with its journal 'European Management Review', instituted to provide a countervailing power to the US-dominated Academy of Management.

To promote their careers, junior scholars are well advised to focus on one such community, establish personal connections with the gatekeeping editors or members of editorial boards, at the requisite conferences or PhD schools, carefully cite their work, and submit work that is marginally innovative but not too deviant from established doctrine. Once they have built up a position of prestige, they may be able to afford larger departures from the newly developed mainstream, but the question is whether they still have the originality of mind to do so, and whether they may be motivated to deviate from the foundations of the prestige that they have so painstakingly built up.

This social dynamic indeed yields isolating mechanisms between communities, raising strong obstacles to interdisciplinary research. Connecting A and B, and saying A things to B and B things to A, one finds that for both part of what one is saying falls outside absorptive capacity and is at best fiercely criticized for its unorthodoxy or is at its

worst, and most likely, simply ignored. If senior scholars do deviate from doctrine, and bridge holes between disciplines, and starting young scholars come to them for guidance, a moral dilemma arises. Should they lead such young scholars astray, into the no-man's land of interdisciplinary research, and have them pay the price of lack of visibility and attention that impedes their career? One should clearly warn them of this risk, dissuade them to take it, and coach them only if they decide to accept it anyway and live dangerously.

The strength of selection and isolation between disciplines varies. To the extent that hypotheses are more clearly and rigorously falsifiable, as is the case to a larger extent in natural science than in behavioural science, selection is more stringent, and cross-disciplinary research can more easily be vindicated by empirical success. Then, the selection mechanism is more rigorous, and in that sense in line with Darwinian evolutionary theory, but inter-group isolation is less, in contrast with such theory.

6.3 SOURCES OF VARIATION

In this paragraph I analyze sources of variation, i.e. the generation of new knowledge and competencies, or, in other words, dynamic capabilities (Teece et al. 1997). The question is how invention takes place, and how blind or directed it is. I propose three sources: transformation of meaning in communication, transformation by novel combinations of existing knowledge, in learning by interaction, and experience-based learning on a path of exploitation that leads up to exploration. While the first of these is largely blind and accidental, the second can be deliberate and designed (Nonaka and Takeuchi 1995, Zollo and Winter 2002), and the third is directed by selection and can also to some extent be designed (Nooteboom 2000).

Variation by Communication and Collaboration

As indicated earlier, absorption or assimilation is to a greater or lesser extent accompanied by expansion and transformation of the knowledge absorbed, and it can lead to a break and transformation of the interpretative structures that constitute absorptive capacity. In that sense, communication not only yields 'replication', but also contributes to the generation of variety. In communication, in expression by the 'sender' tacit knowledge can never be fully codified and externalized so that expressed knowledge is always incomplete, and in absorption, or assimilation, knowledge is complemented and supplemented from the existing cognitive framework of the 'recipient'. Furthermore, what is 'left out' by the sender and what is 'added' by the receiver, and how this is done, depends on clues from the context. Thus, meaning is always context dependent (though not completely context determined).

This source of variation is indeed, as expected from an evolutionary perspective, blind, accidental, and not deliberate, planned or designed. Using the four criteria of blindness suggested by Campbell (1974), indicated earlier, it is blind in all but one aspect: they do not seem to be independent from each other, but to cohere in a 'seamless web' of cognition. However, while the process itself is blind, it can be influenced by the selection of interactors and the context of interaction.

March (1991) suggested that the generation of new ideas, in exploration, follows from personnel turnover, where people from outside an organization carry fresh ideas into the

organization that may disturb the efficiency of exploitation but contribute to exploration. That is certainly part of the process of variation, but it is also limited due to the isolating mechanisms indicated before, especially between industries, self-selection of entrants to fit organizational focus, and socialization into that focus.

More generally, new knowledge and competence can be generated deliberately and by design by seeking novel combinations of existing knowledge, in collaboration between different people and organizations. Nonaka and Takeuchi (1995) recognized this as innovation by 'combination', and Zollo and Winter called it 'deliberate learning', in contrast with experiential learning. While Nonaka and Takeuchi as well as Zollo and Winter claimed that such learning by combination requires articulation and codification of the knowledge involved, I disagree. While codification certainly has its advantages, it is neither necessary nor fully possible. Knowledge can never be fully articulated and codified, and a greater or lesser degree of tacitness necessarily remains. Novel combinations of tacit knowledge can also arise without articulatation, in close collaboration in teams.

As analyzed before, in learning by interaction one runs into both the problem and the opportunity from cognitive distance: greater distance makes mutual understanding and acceptance (absorptive capacity, ability to collaborate) more difficult, but also generates novelty value. If the first decreases, say linearly, with cognitive distance, and the second increases with it, and performance of learning by interaction is the mathematical product of absorption and novelty value, an inverse U-shaped relationship results, with an optimal cognitive distance, large enough to yield novelty value but not so large as to preclude understanding and collaboration (Nooteboom 1999). This optimum is not fixed. In particular, absorptive capacity depends on the accumulation of knowledge and competence from past R&D, production, marketing, organization, and, in particular, experience in collaborating with others at sufficient cognitive distance. In other words, experience in dealing with others who think differently yields competitive advantage. An increase of absorptive capacity yields an increase of optimal cognitive distance. For an empirical test, see Nooteboom et al. (2007).

Inter-organizational collaboration requires cognitive coordination and governance of relational risks. For governance there is a toolbox of instruments such as: contracting plus requisite monitoring, in so far as feasible in view of uncertainties of environment and behaviour, a balance of mutual dependence, posting of hostages, typically in the form of competitively sensitive information, reputation mechanisms and trust building, by cultural alignment of values, personal empathy and identification and routinization of conduct (Nooteboom 1999).

In conclusion, one type of dynamic capability is the ability to find partners, at optimal distance, and to effectively understand and collaborate with them, in the governance of 'relational risk'. This dynamic capability in the form of alliance capability can be developed by building absorptive capacity and experience in communicating and collaborating with partners who think differently.

Now, in view of all this, how blind is variation by collaboration? Collaboration requires communication and as indicated this is always imperfect, and can yield unintended and unnoticed variation. That is one reason why collaboration is blind in the sense that it is subject to more or less random disturbance and fluctuation of interpretation and meaning. It is also blind in the sense that one cannot predict the precise

outcome of learning by interaction, since it is not based on experience, unless collaboration is embedded in some experiential process, to be discussed later. However, it is not blind in that it is informed by selective success: one selects partners in learning who have demonstrated to be competent in some respect. It is designed: one may have a fair guess of cognitive distance and select partners at optimal distance. Applying Campbell's (1974) criteria of blindness, variations from planned collaboration are not independent, are not separate from the environment, and later variations can be corrections of former ones. They are not, however, correlated with the solution, in the strong sense that the outcome can be predicted.

A Heuristic of Invention

From Nooteboom (2000) I adopt a 'heuristic of invention' or 'cycle of discovery', according to which exploration of novel ideas may arise along different stages of exploitation of existing practices under novel conditions (generalization) that pose new challenges, with resulting failures that generate pressure, motivation and fresh insight for change. First with minor modifications tapped from a fund of earlier experience (differentiation). Subsequently, if failure persists, other practices in the novel environment that seem to perform well where one's own practice seems to fail suggest elements that may be imported into one's practice to improve performance (reciprocation), without yet surrendering the basic design, architecture or logic of existing practice. This is stage of experimenting with hybrids, of one's own and foreign practice, that enables one to try out and discover the potential of novel elements. When such potential materializes, evidence is also accumulated as to where current basic design or logic inhibits the realization of full potential, and indications are gathered as to where and in what ways design might be altered to better realize potential. This may yield the basis for more radical transformation, in novel architectures of old and new elements according to old and/or new design principles (transformation). That may yield an invention, which next has to be carried into application, in a process of development towards a 'dominant design', and subsequent consolidation in appropriate forms of organization and institutions to further accommodate proven success, as amply described in the innovation literature.

This heuristic is proposed as a general 'logic' that may manifest itself in several ways. It may govern how novel mental structures arise, in reciprocation of formerly distinct parallel neural groupings in the brain (Edelman 1987). The stage of generalization, in an exit into a novel context, appears to correspond with the well-known phenomenon of 'spin-off' in the innovation literature. The process is recognizable in the literature on innovation by internationalization of firms. While formerly internationalization was primarily a strategy to maintain growth after saturation of home markets, it un-intendedly set in motion the process of discovery, which companies then started to identify and understand as such, and subsequently have started to employ as a deliberate strategy of innovation. Above all, perhaps, the 'logic' explains why innovation by collaboration, at appropriate cognitive distance is effective. Having to explain one's knowledge and practice to a partner in collaboration entails a step of generalization, where one obtains new insights into the limits of one's views and practice, yielding a need to adjust, first on the basis of reframing it on the basis of previous experience. Next when that does not work, partners in collaboration offer each other sources of

reciprocation, in an exchange of novel elements to try out, and in exchanging design principles in search of solving the constraints and problems that arise from the resulting hybrids. It is much easier to have a partner to stimulate and assist the process than having to do everything by one's own inference.

This may contribute to a deeper understanding of the familiar notion of 'absorptive capacity': having more experience, one is better able to reframe, in cognition and competence, what a partner offers in the process of reciprocation. Earlier, I indicated that the other side of the coin of learning by interaction is rhetorical ability, to help a partner absorb what one offers to him, notably by the use of apt metaphors. The more experience one has, the greater the fund of one's metaphors is.

Here the question is what the implications are for evolutionary theory.
There is an empirical literature on *punctuated equilibria* in technological development (Tushman and Romanelli 1985, Tushman and Anderson 1986, Romanelli and Tushman 1994, Gersick 1991). While detecting that phenomenon empirically, this literature has not offered an adequate theoretical explanation. As noted in Nooteboom (2000) in evolutionary biology Eldredge and Gould (1972) and Gould (1989) offered at least the beginning of an explanation of punctuated equilibria, on the basis of 'allopatric speciation'. There, the origin of new species is attributed to a long process outside of, or at the margin of, parent niches, where there are opportunities for experimentation with novel forms without their being swamped by the dominant species in the parent niche. Punctuation is rare, relative to long periods of stability, because it takes a long process of outside trial and error to establish a new form that is strong enough to turn around and successfully invade the parent niche.

This point of evolutionary 'logic' resembles the principle of generalization in the 'cycle of discovery' set out here, with its exit to a novel context of application. However, upon scrutiny the underlying logic is different. In evolutionary theory it is only the criteria of selection that change, offering new challenges and opportunities for survival and reproduction that cause a phylogenetic drift away from the parent population since interbreeding is blocked by some physical obstacle to interaction. Here, by contrast, the novel environment is a source of novel insights into limitations of existing practice, a build-up of motivation to change, and, most importantly, suggestions for novel elements that might be tried out, in hybridization, and novel architectural principles to eliminate problems caused by hybrids. Also, while the shift of environment may be imposed unexpectedly from the outside, when disaster strikes or an invading competence destroying innovation forces one to adapt, it may also be undertaken voluntarily and by design, in a deliberate step into a novel context of application, seeking optimal cognitive distance.

A key question now is how blind this source of 'variation' is. It is blind in the sense that the innovative outcome of the process cannot be predicted. However, it is not blind in that novel selection environments can be selected purposely, as likely to generate opportunities to continue exploitation while yielding novel challenges and indications of elements and directions for exploration. The process is informed by success and failure in selection. Applying Campbell's (1974) criteria of blindness, variations from the process are not independent, are not separate from the environment, and later variations can be corrections of former ones. They are correlated with the solution, in the sense that

experience with failure and indications of solutions inform the process. However, the outcome still cannot be predicted.

6.4 CONCLUSIONS

When evolution is abstracted from biological evolution, in 'Universal Darwinism', with only the bare notions of variety generation, selection and replication, without specification of how those processes work, it can to some extent be made to fit socio-economic evolution. The attempt to maintain an evolutionary perspective is useful for developing a coherent combination of internal and external causes of change, and of agency and structure, avoiding both an overly rational view of managerial design and a view of environmental determinism without actors. However, with such a bare, abstracted framework, most of the explanatory work still has to be done. A key question is whether a further elaboration of the framework in terms of interactors and replicators can meaningfully be sustained, and here my doubts are more severe. To the extent that this is a requirement for universal Darwinism, I share the doubts and criticisms of the latter that were voiced before by Witt (2005) and Nelson (2006). With this paper I aim to make a further contribution, building on the organizational literature, focusing on issues that have been most neglected or incompletely developed in previous literature. First I focus on organizations, and subsequently I consider science.

Organizations

I specified four issues, concerning:

- The nature of the replicators carried by organizations interpreted as interactors, the sources of cohesion and stability of organizations as interactors, and the causes and extent of their differences within and between industries interpreted as populations
- The extent to which the selection environment of markets and institutions can be molded by organizations.
- The nature of replication, and its relation to variety generation
- How blind variety generation is, and the extent to which it may be guided by design and by learning from selection

In an attempt to deal with these issues, I offered an analysis on the basis of a 'cognitive theory of organization', which is in turn based on an 'embodied cognition' branch of cognitive science that yields, among other things, the notion of 'cognitive distance' between people to the extent that they have developed their cognition along different life paths.

Concerning the first issue I offer the notion of an organization as a 'focusing device', to limit cognitive distance for the sake of efficient achievement of collective organizational goals. It consists of a culturally constituted, socially generated and maintained bundle of replicators, if one wants to try that term, in the form of basic perceptions, interpretations, meanings and value judgements concerning goals, priorities, knowledge, strategy, work, technology, jobs and roles, on the competence side, and norms and values of conduct and conflict resolution, on the governance side. These yield requisite cohesion and stability of organizations, intra-industry differences mostly on the governance side, inter-industry differences on both the competence and the governance

side, and limited possibilities for integral and instantaneous revision of replicators (organizational cognitive focus) by the interactor (organization), thus implying a certain amount of inertia. The analysis also allows us to drop clear and stable boundaries of activities as part of the definition of organizations.

This may be sufficient to maintain the notion of organizations as interactors. However, the notion of replicators is more problematic, if the notion entails that the replicators:

1. are carried by interactors,
2. generate characteristics of interactors relevant for success and replication,
3. are embodied in interactors, i.e. cannot exist apart from them,
4. and are not shaped by interactors in ways that reliably reflect exigencies of the selection environment

If for organizational replicators we take organizational capabilities, the first two conditions are reasonably satisfied, the third is clearly violated, and the fourth is subject to debate. In so far as all conditions are necessary, the notion of replicators does not apply, and if that is the case the notion of evolution becomes dubious. In so far as the notions of both interactors and replicators are needed for Darwinism it is difficult to sustain. This still leaves the possibility that a wider interpretation of evolutionary theory can be sustained, as based on generalized notions of selection, transmission and variety generation.

Concerning the second issue, of selection, without detailed analysis I granted that while indeed markets and institutions can to a greater or lesser extent be molded by organizations, singly or collectively, and in that sense evolutionary selection can be inefficient, significant selection pressures generally remain. Hence this aspect of evolutionary theory can reasonably be maintained.

Concerning the third issue, of transmission, I gave an analysis of replication on the basis of communication, and of how next to very imperfect replication this also yields variety generation. However, while in communication there is much decay, reduction, expansion and transformation of knowledge and competencies, some similarity in transmission remains. The question is whether such similarity is 'sufficient' to count as replication. I am afraid that treating communication as replication puts the analysis on the wrong foot, and it would be better to fully recognize communication and language as categories on their own that merit a *sui generis* analysis, using theories of language and meaning (Nooteboom 2001).

Concerning the fourth issue, of variety generation, I argued for the intelligent design of innovation by collaboration, and of a path of cumulative insight and experience guided by selection in a variety of chosen selection environments that is conducive to outcomes that are unpredictable but have an enhanced chance of success. The heuristic of invention, or cycle of discovery, proposed by Nooteboom (2000), yields a form of inference and learning from experience concerning selection conditions that leads to the shaping of new selection conditions, which can hardly be called blind and is correlated with selection processes. While its specific outcomes are indeed unpredictable, overall performance is predictable, and the process is subject to rational design to some extent. Here also, to see it as 'variety generation' may put the analysis of the wrong foot, and it would be better to fully recognize learning processes as meriting a *sui generis* analysis, using theories of cognition and learning (Nooteboom 2001).

Overall, the component evolutionary processes of variety generation, selection and transmission are far more interrelated than in biology, with units of selection being more able to mold selection conditions, interactors being able, to some extent, to change their replicators, replication entailing the generation of variety, and ways in which experience in selection can direct variety generation.

In sum, as I did earlier (Nooteboom 2001), I am again inclined to rate evolutionary theory as only partially valid in socio-economics, possibly misleading, and hence insufficiently acceptable at least in principle, and adequate only as a stage of development towards a more adequate theory of socio-economic development. As indicated at the beginning, the merit of evolutionary theory lies in offering a view of both agency and structure, and interaction between them. However, there may be other ways to achieve that, which more directly reflect how learning and communication take place, in interaction between actors and their environment.

Science

Concerning cultural evolution more generally, and science in particular, the problems of evolutionary theory are worse. Concerning the first issue, of replicators and interactors, it seems reasonably clear that scientists, and on a higher level of aggregation perhaps also scholarly societies, may be seen as interactors. Like organizations in general, scientific societies may have a shared cognitive focus determining group identity, which may satisfy the condition that interactors must have some coherent, durable identity. However, replicators are even more problematic than in the analysis of organizations. Are they theories, or underlying ideas, or elements from scientific paradigms? In the latter case they would carry all the problems associated with the notion of paradigms. Whatever they are, precisely, here also they 'float around', disembodied from their carriers. It is not entirely clear what the success criterion of selection is. If it is lack of falsification, this entails all the problems that the notion of falsifiability entails, as exhibited in an extensive literature on the philosophy or methodology of science. Here also, replication in communication, in publications, meetings at conferences and seminars and PhD training is more a matter of cognitive reduction, amplification and reconstruction than a matter of replication. As in the case of organizations and their capabilities, the survival and replication of purported replicators is not entirely dependent on success of interactors under selection. Here, in some disciplines more than in others, (even) more opportunities exist to mold the selection environment than in the case of firms in markets, in opportunities to create a selection environment of dedicated scientific associations with their proprietary journals.

Thus, if evolution is problematic in organizations, it is problematic a forteriori in science.

In Sum

In sum, like Nelson (2006) I have problems with the notions of interactors and replicators, particularly with the notion of replicators being tied to interactors and shaping them, more than they are shaped by them. More than Nelson (2006) I also have problems with the basic notions of variety generation, selection and replication/transmission. While I appreciate their value in yielding a view of how agency and structure interact, while avoiding both an overly rational view of agents and environmental determinism, I have

problems with them. Variety generation is not blind and is informed by experience from selection. Selection occurs both internally in the interactor (by mental experimentation) and in its interaction environment, and is subject to collective, political processes. Replication entails transformation and thereby is a form of variety generation. I am afraid that adherence to the terminology of replicators and interactors sidetracks attention from where it should go: to the investigation of learning, in the sense of invention and creation, and investigation of communication and language. Therefore, I would be more comfortable with a different theoretical framing of the processes of invention, selection, and communication. However, I am not sure that it is useful to assign this the label of 'evolutionary theory'. If we drop the conceptual tools of replicators and interactors, doesn't the notion of evolution become too general and loose to yield much theoretical grip? It still serves to indicate an approach that is characterized by attention to dynamics and emergence, rather than rational design and choice, as a result of selection (by markets and institutions) upon a variety of competencies/capabilities (of firms) whose successes are transferred (by growth, imitation, training, consultancy, training, institutionalization, spin-off and other forms of mobility of people). But is that enough? We need to add content to how these processes work, and I believe this is to be done in terms of cognition, learning and communication, which is what in earlier chapters I set out to do.

Answers

Below I summarize a number of questions and the answers offered in this paper.

Question 1: how can we avoid both excessive managerial rationalism and external determinism

Answer: Here lies a great advantage of evolutionary theory: idea generation (variety creation) plus selection and transmission explain the emergence of new forms. While firms can learn and can to a greater or lesser extent affect their survival conditions, they cannot without mistake manage them completely, and some force of selection remains. While trials are informed, much error remains.

Question 2: why are inter-industry differences larger than intra-industry ones

Answer: within industries, sharing technologies and markets to a larger extent than between industries, cognitive distance between firms is smaller, particularly concerning the competence dimension.

Question 3: to what extent are dynamic capabilities informed by demands from selection

Answer: selection pressures may indicate needs and opportunities to experiment with novel combinations, they may trigger an escape to novel selection conditions, and stagnation due to lack of growth or lack of selection may stimulate a shift to novel selection conditions to acquire new insights into limits and opportunities. Such exit may be guided by a search for optimal cognitive distance on the basis of experience in markets. Selection may give useful information about obstacles and opportunities in networks. In other words, 'allopatric speciation' is not necessarily blind.

Question 4: to what extent is there 'inheritance' of acquired characteristics

Answer: firms set exemplars to be imitated or avoided on the basis of how they fare in selection and on the basis of what they have learned in the selection process.

Question 5: to what extent can firms mold their selection environment
Answer: Collectively, participants in successful breakthrough and consolidation of an innovation (producers, users, intermediaries, labour, government) develop institutions (technical, organizational, behavioural, safety-related, educational, reporting and other) standards, market structures (e.g. distribution channels, financial markets), habits (e.g. of consumption) that fit the innovation and improve its efficient exploitation. After consolidation, such established institutions and powerful incumbents can to a greater or lesser extent actively block entry of challengers.

Question 6: to what extent is transmission a source of variety generation.
Answer: in perception and communication meanings are not simply transmitted but transformed in assimilation, yielding novel combinations of old and new perceptions, insights etc. Hence transmission entails variety generation.

References

Aldrich, H. (1999), *Organizations evolving,* London: Sage.

Anderson, P. and Tushman, M. (1990), 'Technological discontinuities and dominant designs: A cyclical model of technological change', *Administrative Science Quarterly*, 35(4), 604-633.

Baum, J.A.C. and Singh J.V. (1994), 'Organizational hierarchies and evolutionary processes: Some reflections on a theory of organizational evolution', in J.A.C. Baum and J.V. Singh (eds), *Evolutionary dynamics of organizations*, Oxford: Oxford University Press: pp. 3-20.

Bleeke, J. and D. Ernst (1991), 'The way to win in cross-border alliances', *Harvard ,Business Review*, November/December, 127-35.

Boyd, R. and Richerson, P.J. (1985), *Culture and the evolutionary process*, Chicago: University of Chicago Press.

Brown, J. S. and P. Duguid (1996), 'Organizational learning and communities of practice', in M. D. Cohen and L. S. Sproull (eds), *Organizational learning*, London: Sage, pp. 58-82.

Burgelman, R.A. (1983), 'A model of the interaction of strategic behavior, corporate context, and the concept of strategy', *Academy of Management Review*, 8, 61-70.

Burns, T. and G.M. Stalker (1961), *The management of innovation,* London: Tavistock.

Campbell, D.T. (1987), 'Blind variation and selective retention as in other knowledge processes', in G. Radnitzky and W.W. Bartley III (eds), *Evolutionary epistemology, theory of rationality, and the sociology of knowledge,* La Salle: Open Court, pp. 91-114.

Campbell, D.T. (1974), reprinted in 1988, 'Evolutionary epistemology' in D.T. Campbell, *Methodology and epistemology for social science*, Oxford: Oxford University Press, pp. 393-434.

Cohen, M.D. and P. Bacdayan (1996), 'Organizational routines are stored as procedural memory', in M. D. Cohen and L. S. Sproull (eds), *Organizational learning*, London: Sage, pp. 403 - 430; first printed in *Organization Science,* 5(4), in 1994.

Cohen, M.D. and D.A. Levinthal (1990), 'Absorptive capacity: A new perspective on learning innovation', *Administrative Science Quarterly*, 35, 128-152.

Coriat, B. (2002[2000]), 'The abominable Ohno production system. Competences, monitoring, and routines in Japanese production systems', in G. Dosi, R.R. Nelson and S.G. Winter (eds), *The nature and dynamics of organizational capabilities*, Oxford: Oxford University Press, pp. 213-243.

Dawkins, R. (1983), 'Universal darwinism', in D.S. Bendall (ed.), *Evolution from molecules to man*, Cambridge: Cambridge University Press, pp. 403-425..

DiMaggio, P.J. and W.W. Powell (1983), 'The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields', *American Sociological Review,* 48(2), 147-160.

Edelman, G. M. (1987), *Neural Darwinism; the theory of neuronal group selection*, New York: Basic Books.

Eldredge, N. and S.J. Gould (1972), 'Punctuated equilibria: An alternative to phyletic gradualism', in T. J. M. Schopf (ed.), *Models in paleobiology*, San Franciso: Freeman, Cooper and Co, pp. 82 - 115.

Foster, J and Metcalfe, J.S. (eds) (2001), *Frontiers of evolutionary economics: Competition, self-organization and innovation policy,* Cheltenham UK: Edward Elgar.

Garud, R. and M. A. Rappa (1996), 'A socio-cognitive model of technology evolution; The case of cochlear implants', in J. R. Meindl, C. Stubbart and J. F. Porac (eds), *Cognition within and between organisations*, London: Sage, pp. 441-474; first published in 1994 in *Organization Science* 5(3).

Gersick, C. J. G. (1988), 'Time and transition in work teams: Toward a new model of group development', *Academy of Management Journal*, 31, 9-41.

Gould, S. J. (1989), 'Punctuated equilibrium in fact and theory', *Journal of social biological structure*, 12, 117-136.

Granstrand, O., P. Patel and K. Pavitt (1997), 'Multi-technology corporations: Why they have distributed rather than distinctive core competencies', *California Management Review*, 39(4), 8-25.

Groot, A.D. de (1969), *Methodology: Foundations of inference and research in the social sciences*, the Hague: Mouton.

Hannan, M. T. and Freeman, J. (1977), 'The population ecology of organizations', *American Journal of Sociology*, 88, 929-964.

Hannan, M. T. and Freeman, J. (1984), 'Structural inertia and organizational change', *American Sociological Review*, 49, 149-164.

Hannan, M. T. and Freeman, J. (1989), *Organizational ecology,* Cambridge MA: Harvard University Press.

Hodgson, G.M. (2002a), 'The legal nature of the firm and the myth of the firm-market hybrid', *International Journal of the Economics of Business*, 9(1), 37-60.

Hodgson, G.M. (2002b), 'Darwinism in economics: from analogy to ontology', *Journal of Evolutionary Economics*,12, 259-281.

Hodgson, G.M. (2006), 'What are institutions?', *Journal of Economic Issues*, 60(1), 1-25.

Hodgson, G.M. and Knudsen, T. (2004), 'The firm as interactor', *Journal of Evolutionary Economics,* 14, 281-307.

Hodgson, G.M. and Knudsen, T. (2006), 'Why we need a generalized Darwinism, and why generalized Darwinism is not enough', *Journal of Economic Behavior and Organization*, 61, 1-19.

Holland, J.H. (1996[1995]), *Hidden order; How adaptation builds complexity*, Cambridge US: Perseus Books.

Hull, D.L. (1988), *Science as process; An evolutionary account of the social and conceptual development of science,* Chicago: University of Chicago Press.

Johnson-Laird, P. N. (1983), *Mental models*, Cambridge: Cambridge University Press

Lachmann, L. (1978) 'An Austrian stocktaking: unsettled questions and tentative answers', in L. Spadaro (ed.), New directions in Austrian economics, Kansas City: Sheed, Andrews & McMeel, 1 - 18.

Lave, J. and E. Wenger (1991), *Situated learning; Legitimate peripheral participation,* Cambridge: Cambridge University Press

Levinthal, D.A. (2000), 'Organizational capabilities in complex worlds', in G. Dosi, R.R. Nelson and S.G. Winter (eds), *The nature and dynamics of organizational capabilities*, Oxford: Oxford University Press, pp. 363-379.

March, J.G. (1991), 'Exploration and exploitation in organizational learning', *Organization Science,* 2(1), 101-123.

McKelvey, W. (1982), *Organizational systematics: Taxonomy, evolution, classification,* Berkeley: University of California Press.

Metcalfe, J.S. (1998), *Evolutionary economics and creative destruction,* London: Routledge.

Miner, A.S. (1991), 'Organizational evolution and the social ecology of jobs', *American Sociological Review,* 56, 772-785.

Nelson, R.R. (2006), Economic development from the perspective of economic theory, The other Canon Foundation and Tallin University of Technology Working Papers in Technology Governance and Economic Dynamics 02, TTU Institute of Humanities and Social Science.

Nelson R. R. and S. Winter (1982), *An evolutionary theory of economic change,* Cambridge: University Press.

Nonaka, I. and H. Takeuchi (1995), *The knowledge creating company*, Oxford: Oxford University Press.

Nooteboom, B. (1992), 'Towards a dynamic theory of transactions', *Journal of Evolutionary Economics*, 2, 281-99.

Nooteboom, B. (1999), *Inter-firm alliances: Analysis and design*, London: Routledge.

Nooteboom, B. (2001), 'From evolution to language and learning', in J. Foster and s. Metcalfe (eds), *Frontiers of evolutionary economics: competition, self-organisation and innovation policy,* pp. 41-69.

Nooteboom, B. (2006), Elements of cognitive theory of the firm, in E. Krecké, C. Krecké, R.G. Koppl (eds.), *Cognition and economics*, Advances in Austrian Economics vol. 9, Amsterdam, 2006: Elsevier: 145-176.

Nooteboom, B. (2009), *A cognitive theory of the firm; Learning, governance and dynamic capabilities,* Cheltenham UK: Edward Elgar, forthcoming.

Nooteboom, B., W.P.M. Van Haverbeke, G.M. Duijsters, V.A. Gilsing and A. V.d.Oord (2007), 'Optimal cognitive distance and absorptive capacity', *Research Policy*, 36, 1016-1034.

Piaget, J. (1970), *Psychologie et epistémologie*, Paris: Denoël.

Piaget, J. (1974), *Introduction a l'épistémologie génétique*, Paris: Presses Universitaires de France.

Popper, K.R. (1959), *The logic of scientific discovery*, London: Hutchison.

Romanelli, E. and M.Y. Tushman (1994), 'Organizational transformation as punctuated equilibrium: An empirical test', *Academy of Management Journal*, 37(5), 1141 - 1166.

Schein, E. H. (1985), *Organizational culture and leadership*, San Francisco: Jossey - Bass

Shackle, G. (1961), *Decision, order and time in human affairs,* Cambridge: Cambridge University Press.

Smircich, L. (1983), 'Organization as shared meaning', in L. R. Pondy, P. J. Frost, G. Morgan and T. C. Dandridge (eds), *Organizational symbolism*, Greenwich Conn: JAI Press, pp. 55-65.

Spender, J. C. (1989), *Industry recipe,* Oxford: Basil Blackwell.

Teece, D., G. Pisano and A. Shuen (2000), 'Dynamic capabilities and strategic management', in G. Dosi, R.R. Nelson and S.G. Winter (eds), *The nature and dynamics of organizational capabilities*, Oxford: Oxford University Press, pp. 334-362

Tushman, M.L. and E. Romanelli (1985), 'Organizational evolution: A metamorphosis model of convergence and reorientation', *Research in Organizational Behavior*, B. A. Staw and L. L. Cummings, Greenwich Conn.: JAI Press, pp. 171 - 222.

Tushman, M.L. and P. Anderson (1986), 'Technological discontinuitties and organizational environments', *Administrative Science Quarterly*, 31, 439-465.

Weick, K.F. (1995), *Sensemaking in organisations*, Thousand Oaks CA: Sage.

Weick, K. F. and K.H. Roberts (1993), 'Collective mind in organizations', *Administrative Science Quartery*, 39, reprinted in Michael D. Cohen and L. S. Sproull (eds), *Organizational learning,* 1996, London: Sage, pp. 330-358.

Witt, U. (2004), 'On the proper interpretation of 'evolution' in economics and its implications for production theory', *Journal of economic methodology*, 11, 125-146.

Witt, U. (2005), 'The evolutionary perspective on organizational change and the theory of the firm', in K. Dopfer (ed.), *The evolutionary foundations of economics*, Cambridge: Cambridge University Press pp. 339-364.

Wittgenstein, L. (1976 [1953]), *Philosophical investigations*, Oxford: Basil Blackwell.

Wuyts, S, M.G. Colombo, S. Dutta and B. Nooteboom (2005). 'Empirical tests of optimal cognitive distance', *Journal of Economic Behavior and Organization*, 58(2), 277-302

Zollo, M. and S.G. Winter (2002), 'Deliberate learning and the evolution of dynamic capabilities', *Organization Science*, 13(3), 339-351.

[i] A recent example reported in the press is the finding that while children do not have an inborn fear of snakes, they have an inborn proclivity to notice snakes, more than most other animals, allowing them to rapidly develop a fear of them when appropriate.

[ii] In terms of N/K spaces, with N dimensions and with 'fitness' a function of a systemic whole of N features each of which on average depends on K other features, the landscape is 'rugged', with sharp peaks of fitness at different locations in the space (Levinthal 2000).